

CHAPTER 5

STANDBY POWER SYSTEM

5-1. Description of standby power system

The following is a sample standby power system with associated one-line and wiring diagrams for use as a guide for implementing the test procedures described in the preceding chapters of this manual. A system functional performance test shall be performed on the system. The system shall be operated through all modes of systems operation including every interlock and conditional control logic, full load and part load conditions, and simulation of all abnormal conditions where there is a specific condition response. The system consists of the following equipment: 480V switchgear with utility, generator switchgear, and 500 KW, 480V generators with control panel, and synchronizing/paralleling panel. The equipment, accessories, interconnections, ratings, cabling, etc. are shown on figures 5-1 through 5-3. Figure 5-1 is the standby power system single line diagram on page 5-6. Figure 5-2 is the standby power system block diagram on page 5-7. Figure 5-3 is a diagram of the standby power system wiring on page 5-8. The system provides normal and standby 480V power to the Facility. Under normal conditions power is supplied from the utility through the Utility Power Center to the Facility Plant Load Center which feeds the facility loads. When utility power is lost, the diesel generators will supply power through the utility load center until normal power is restored. The 480V switchgear is metal enclosed and free standing with drawout air power circuit breakers. The main utility, generator breakers, and the facility load breaker are electrically/manually operated. The breakers have instantaneous short time and long time settings. Breaker controls and indication are located on the door of each breaker compartment. The main bus and incoming line have potential transformers connected to a synchronizing check (25) relay, and an undervoltage (27) relay. The 25 relay will not allow the utility breaker to be closed unless the switchgear bus and utility line are synchronized. The 27 relay opens the utility line breaker upon a loss of power (i.e. undervoltage). The 500 kW, 480 V Generator sets include air cooled individual four cycle diesel engines, three phase, four wire generators, and paralleling/synchronizing control systems. The control system allows starting, stopping, loading, paralleling, and synchronizing of the generator to the system in the auto or manual mode while monitoring for equipment and system problems.

5-2. Operation of standby power system

The operating modes for the systems are as follows. These steps would be included in the systems operating document (SOD).

a. Normal condition. Under normal conditions, the utility power supply is energized, the utility breaker is closed, the load center circuit breaker is closed and the circuit breakers for the individual generators are open. The generators are not operating.

b. Loss of power. In the event of the loss of utility power, the utility power center 27 relay sends an open signal to the utility breaker, the load center circuit breaker, and a start signal to the generators. The generators operate either automatically or manually depending on mode selected. The generators will follow each other for load sharing and phasing. In the automatic mode, when the first generator is at the proper operating voltage and frequency, the controls system sends a close signal to that generator's breaker. This generator becomes the lead machine. As the next generator picks up speed, the controls system compares the outputs from that generator's potential transformers and the bus potential transformer and when the voltage and frequency are synchronized, a close signal is sent from the synchronizer to the second generator breaker. This process is again repeated for the third generator. When all available generators are operating in parallel, a signal is sent to close the load center circuit

breaker. In manual operation, the operator controls the diesel generator voltage and speed until the diesel generator is synchronized with other generators and then manually closes the diesel generator breaker. The operator repeats this process for each diesel generator set and then manually closes the load center circuit breaker.

c. Paralleling with utility. In the event that it is desired to parallel with the utility, the system will operate in either the automatic or manual mode. In the auto mode, the generators will automatically synchronize with the utility bus and their breakers will close. In auto/manual mode, the generators will automatically synchronize with the utility bus but the breakers will be manually closed. In manual operation, the operator controls the generator voltage and speed until the diesel generator is synchronized with the bus voltage and then manually closes the diesel generator breaker. The operator repeats this process for each diesel generator set.

d. Restoration of utility. In the event of a loss of utility power the generators are running and supplying the load. The utility breaker is open and all of the generator breakers are closed. When the utility power is restored, the operator manually adjusts the generator speed and voltage very slowly until the sync check relay on the utility load center is energized and illuminates the sync check light. The operator manually closes the utility breaker and then manually trips the generator breakers at the generators control panels. For systems that employ automatic synchronizing devices, it is possible for the system to synchronize to the utility and transfer power from the generator sets to the utility without operator intervention. The automatic synchronizing devices adjust the generator speed and voltage until the generator is in sync with the utility. Then the utility breaker is automatically closed and the generator breaker is automatically tripped.

5-3. Commissioning plan for standby power system

A system verification and functional performance test should be performed on the standby power system. These tests will include installation inspections and individual component testing verification and ring out of wiring, control and interlock function checks, equipment energization, and system operating measurements and functional tests.

5-4. Installation inspections and component testing of standby power system

As indicated in chapter 3, the installation of main components (i.e. generator, switchgear, cabling) each will be inspected or tested for the following. These checks can be considered part of the pre-checks or functional performance tests (FPTs).

a. Generator. Completeness of assembly, proper nameplate data, loose parts and insulation damage, generator air gap and free rotation, generator insulation resistance (phase-to-phase and phase-to-ground), generator polarization index, grounding and proper voltage and phase connections. Figure 5-5 on page 5-10 and 11 shows a sample of a completed DA Form 7468-R for the generator inspection.

b. Engine. Completeness of assembly, proper nameplate data, loose parts, and proper lubrication.

c. Switchgear. Completeness of assembly, proper nameplate data, loose parts and insulation damage, breaker alignment and manual operation, proper relay settings, bus insulation resistance (phase-to-phase and phase-to-ground), grounding, proper voltage and phase connections and potential transformer and control fuse size and continuity. See Figure 4-10 on page 4-16 for sample checklist (DA Form 7465-R).

d. Cabling. Proper use of voltage connections, tightness and neatness of terminations, power cable insulation resistance (phase-to-phase and phase-to-ground). See figure 4-11 (DA Form 7466-R) for sample checklist.

e. Visual and electrical wiring inspections. The termination of each cable, shown on the cable block diagram, shall be checked to ensure each conductor matches the wiring and schematic diagram. This is performed by yellowing each connection from the schematic to the wiring diagram; visually inspecting each connection; and checking the continuity or "ringing out" each wire end to end including grounds. For example Cable PWR1 from Diesel Generator 1 to the 480V Load Center should be checked to verify that the "black" wire is terminated as follows which is shown on figure 5-3:

Equipment	Terminal No.
Diesel Generator 1	L1
480V Load Center	T1

As this is done, the wire on each drawing should be colored or highlighted to show its termination has been checked. This process should be completed for all field wiring as a minimum and internal wiring if not previously performed at the factory.

f. Check control functions. Individual circuits of each component shall be energized and checked for proper function.

(1) Generator. Energize control circuit with outgoing circuit breaker open and verify correct operation of indicating lights, alarms, analog outputs and status outputs (list). Locally start the generator following the manufacturer's instructions for energizing and starting. Verify machine comes up to speed and correct operation of indicating lights, alarms, analog outputs and status outputs. Measure output voltage and frequency. Check remote stop and then remote start functions, external load set function, watt/VAR/voltage outputs, trip and circuit breaker interlocks and other no-load functions specifically required by the generator instruction manual, if any. Energize and verify the operation of any accessory circuits (i.e. generator heaters, fuel heaters, battery chargers).

(2) 480V switchgear. Verify manual operation and local position indication of the main and generator breakers with feeder cables disconnected or breakers racked out. Check the calibration of undervoltage and sync relays in the main breaker control circuit per the manufacturer's instructions. Energize the main breaker control circuit and close the breaker electronically using the control switch. Verify proper operation of lights. Trip the main circuit breaker using the control switch and the undervoltage relay. Verify the 27 relay is not engaged when the switchgear bus is deenergized.

5-5. Energizing and test of the standby power system

In order to energize and test the standby power systems the following procedures must be completed.

- a. Initial set-up.* Verify that generator circuit breakers are open and the generators are ready to start
- b. Bus test.* Close 480V switchgear main and feeder breakers, check voltage on bus, and verify 27 relay is energized. Read voltage and current on bus.
- c. Manual sync/paralleling test.* While 480 V switchgear bus is energized, place each generator in the manual sync mode. Start the first generator and verify it comes up to speed and is ready to take load (a load bank should be used). Manually adjust the speed and voltage of the first generator to be in sync with the 480V switchgear, verify with phase meters that both are in sync and close the first generator's circuit

breaker. Verify that the generator picks up load. Measure voltage, current and frequency. Repeat this process for the other two generators. As each generator is connected, verify load is shared equally between the generators. Measure the voltage, current and frequency for each generator as it is connected. Repeat the entire process starting with the second generator and then again starting with the third generator to ensure that any one of the three generators can act as the starting generator.

d. Auto sync/paralleling test. Repeat the previous step with each generator in the auto sync mode. Each generator should automatically synchronize and close into the 480V switchgear bus.

e. Utility trip load test. Verify that the 480V main breaker is closed and the switchgear is energized. Measure voltage and current on the bus. Verify that the generator breakers are open and the synchronizers are in the auto mode. Trip the 480V main breaker (remove normal power supply). This causes the load center circuit breaker to open. Verify that all three generators start, synchronize, and pick up load (load center circuit breaker closes). Add load until each generator is fully loaded. Run the system for at least 4 hours powered only by the generators. Reconnect utility power and note if sync check relay in the 480V utility breaker is picked up. If not, slowly adjust the speed and voltage of the first generator until the relay is picked up indicating the generators are in sync with the utility. The speed and voltage of the second and third generators should follow the first generator as it is adjusted. Verify that the 480V switchgear bus voltage is in sync with the utility with a phase/voltage meter and close the 480V main breaker.

f. Checklists. In addition to the component test forms discussed above, checklists for utility and generator circuit breaker inspection (see figure 5-6 for completed sample of DA Form 7469-R) and back-up power system inspection (see figure 5-7 for completed sample DA Form 7570-R) must be satisfactorily completed.

g. Modified sequence of operations. The standby power system should be operated in commissioning for all possible sequences of operations that a system will encounter.

5-6. Possible failures and corrective actions of standby power system

Table 5-1 lists general problems that may arise during the testing of the equipment and systems along with possible troubleshooting techniques. For all problems, consult the equipment and component manuals for troubleshooting directions, check fuses/lights/breakers/etc. for continuity, check equipment calibration and settings, and look for faulty equipment or connections. Engine manufacturers typically provide a fault tree for troubleshooting problems. Figure 5-4 is a typical fault tree. The fault tree tracks the symptoms of the problems to identify the most probable cause. For example, if the engine will not run and the starter turns the engine slowly then there is a problem with the battery. The causes of the problem are either loose or dirty connections or a discharged battery.

Table 5-1. Possible failures and corrective actions of standby power system

Engine Problem	Areas to Check
Will not start	Starter, battery, and connections; fuel system, level, pump, injectors, internal engine (valves, tappets, pistons), ignition system (gas engines) control system interlocks/permissives, mis-wired circuits
Poor Performance/Will not handle load	Fuel system and cleanliness, injectors or carburetor, internal engine, control and ignition system, system kW requirements

Table 5-1. Possible failures and corrective actions of standby power system (continued)

Generator Problem	Areas to Check
No Output Voltage/Current	Check stator and rotor continuity, battery fluid level, diode pack, voltage regulator, control system and interlocks, miss-wired circuits
Failure to synchronize	Mis-wired circuits, blown PT fuses, governor/regulator not calibrated properly
Failure to share load	Mis-wired circuits, governor/regulator not calibrated properly

480V Switchgear Problem	Areas to Check
Breakers won't close	Mechanical alignment/ interlocks, control circuit operation, relay and protective device settings and operation, close coil and mechanism, mis-wired circuits. Check control voltage.
Breakers won't trip	Trip coil and mechanism, control circuitry operation, mis-wired circuits
Breakers trip inadvertently	Ground on bus or outgoing cable, relay and protective device settings and operation, control circuitry operation, mis-wired circuits. Check control voltage.

Back-Up Power System Problem	Areas to Check
Generator Breakers will not close	Control circuitry operation, auto/manual sync system, generator control system, mis-wired circuits. Check control voltage.
Generator will not pick up load or stalls/trips	Engine fuel and control system, generator voltage regulator, generator control system, auto/manual sync system, protective device settings, mis-wired circuits
Generators don't share load	Paralleling control system, mis-wired circuits, interconnecting unit control wiring governor control systems, voltage regulating systems
Main switchgear breaker won't re-close on diesel generator powered system	Generator sync system, breaker sync check relay, breaker control circuitry, mis-wired circuits. Verify "as built" reflect actual circuit conditions.

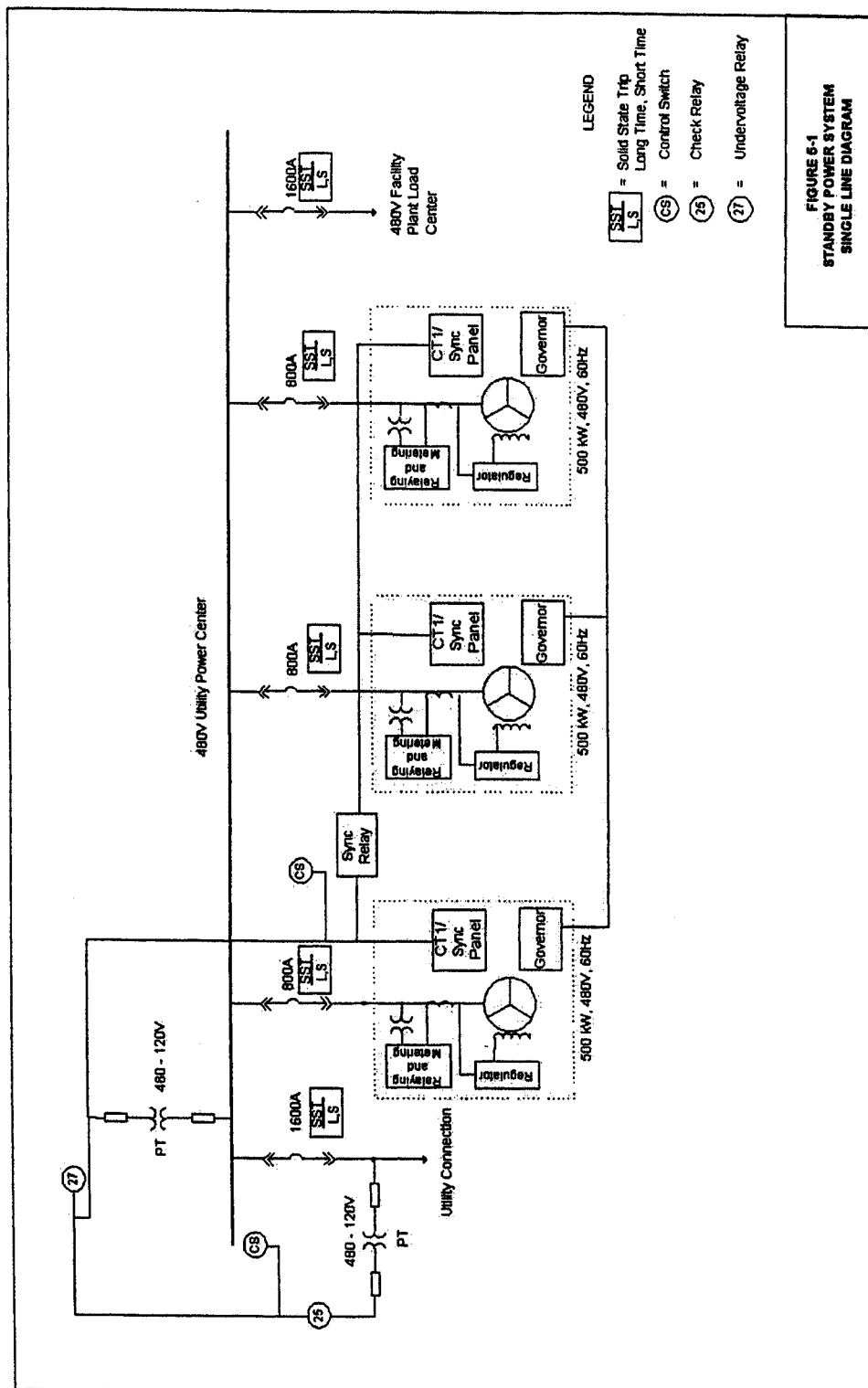


FIGURE 5-1
STANDBY POWER SYSTEM
SINGLE LINE DIAGRAM

Figure 5-1. Standby power system single line diagram

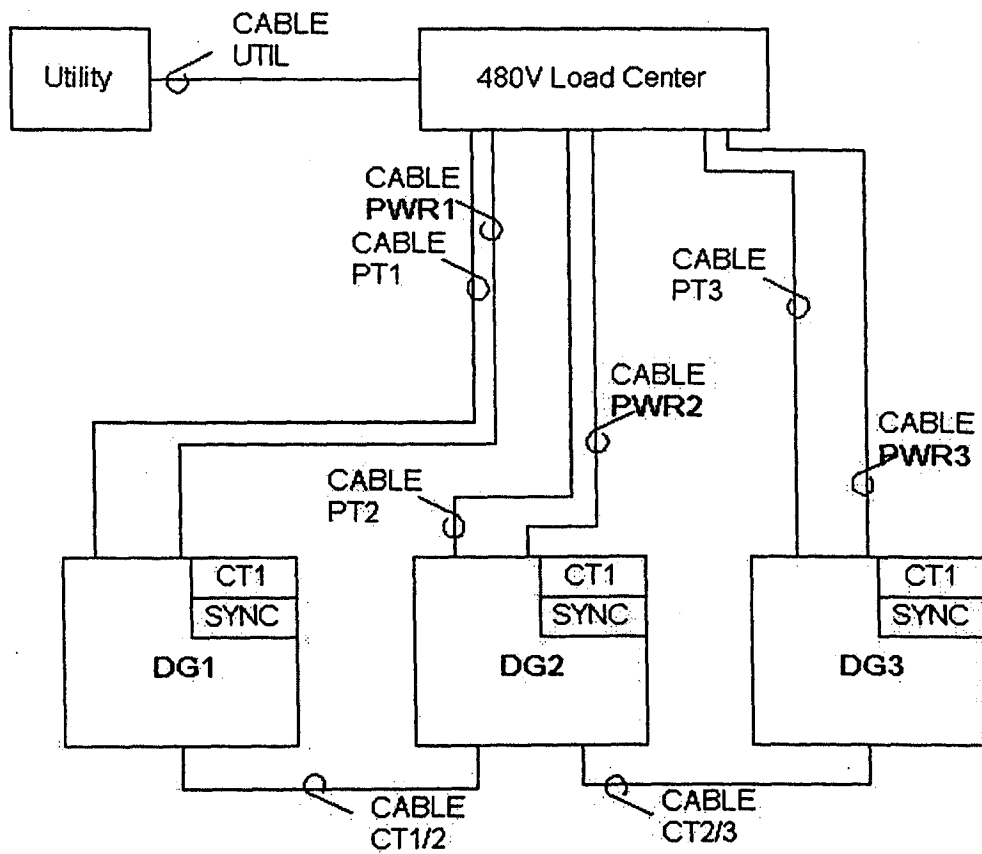


FIGURE 5-2
STANDBY POWER SYSTEM
BLOCK DIAGRAM

Figure 5-2. Standby power system block diagram

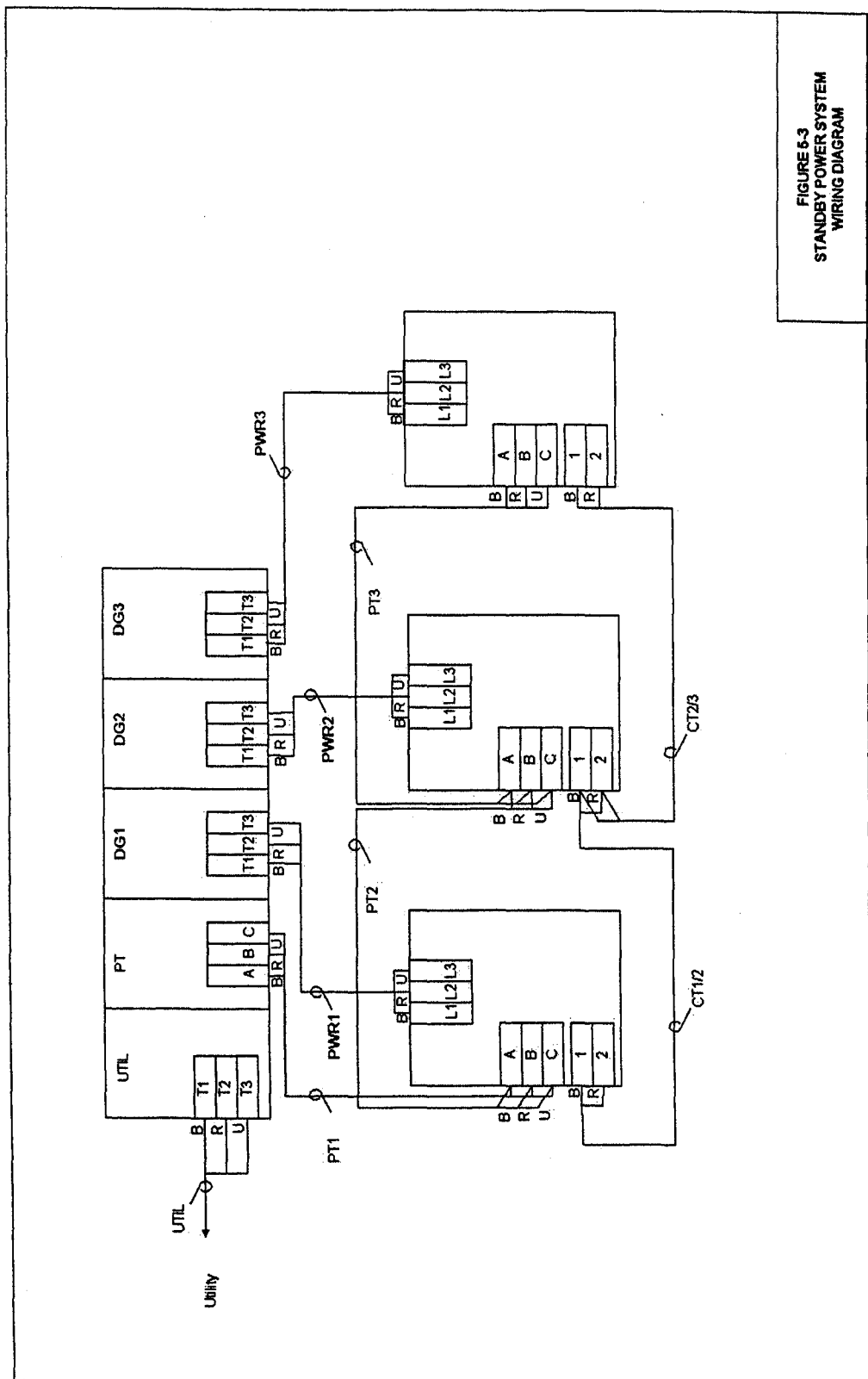
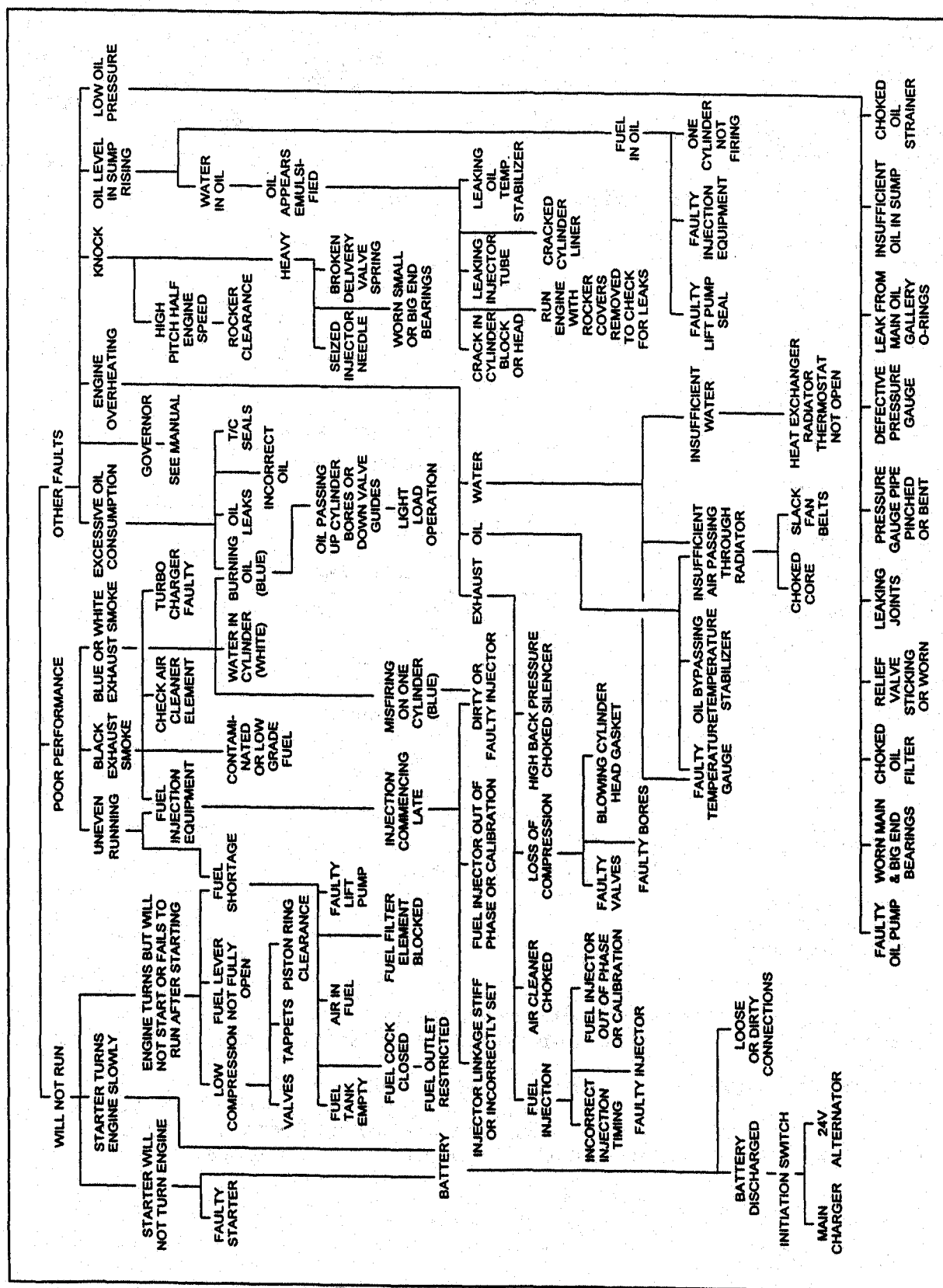


Figure 5-3. Standby power system wiring diagram



ENGINE GENERATOR SET INSPECTION CHECKLIST

For use of this form see TM 5-694; the proponent agency is COE.

SECTION A - CUSTOMER DATA

1. PLANT/BUILDING Bldg 1929	2. LOCATION Fort Tank	3. JOB NUMBER 02-122
4. EQUIPMENT Genset	5. CIRCUIT DESIGNATION G1	6. DATE (YYYYMMDD) 20020823
7. TEST EQUIPMENT TYPE/BRAND AND CALIBRATION DATE Biddle Insulation Tester/ 5 July 2002		8. TESTED BY John Smith

SECTION B - EQUIPMENT DATA

9. MANUFACTURER CAT	10. STYLES/S.O. Diesel 3416	11. VOLTAGE RATING 4160	12. KW RATING 500kW
13. CIRCUIT BREAKER SIZE/INTERRUPTING RATING 300A/ 50kA		14. WET BULB TEMPERATURE 65 F	15. DRY BULB TEMPERATURE 85 F

SECTION C - VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

16. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
EXTERIOR OF EQUIPMENT	A		EQUIPMENT IDENTIFICATION	A	
COMPLETENESS OF ASSEMBLY	A		BRACING	A	
EQUIPMENT ROTATION	A		PROPER PHASE CONNECTIONS	A	
CHECK OIL LEVEL	A		REFERENCE DRAWINGS	A	
CHECK FUEL LEVEL	A		WORKING CLEARANCE	A	
PROPER EQUIPMENT GROUNDING	A		ANCHORAGE	A	
CHECK METERS/GAUGES	A		ALL FILTERS AND VENTS CLEAR	A	
TIGHTNESS OF BOLTED CONNECTIONS	A		CHECK EQUIPMENT ENVIRONMENTAL CLASSIFICATION	A	
VERIFY GOVERNOR AND REGULATOR	A		CHECK FOR PROVISIONS OF SPILL CONTAINER	A	
CHECK VIBRATION	A		CONTROL SYSTEM	A	
CHECK BATTERIES	A		CHECK FUEL FILTER	A	
CHECK RADIATOR FLUID	A		CHECK ALARM INDICATORS: PROPER COLOR FOR EACH FUNCTION	A	
PROPER SYSTEM GROUND	A				

SECTION D - ELECTRICAL TESTS

17. INSULATION RESISTANCE @ 2500 V	A-GRD	B-GRD	C-GRD	A-B	B-C	C-A
	10 megohm	12 megohm	14 megohm			
POLARIZATION INDEX RATIO - 10 MINUTE/1 MINUTE	2.1	2.2	2.3			
DC OVERPOTENTIAL TEST @ V	notes 1 & 2					

18. NOTES

1. PERFORM 5 MEASUREMENTS AT ONE MINUTE INTERVALS.
2. DC HIPOT MEASUREMENTS SHOULD BEGIN AT 20% OF MAXIMUM TEST VOLTAGE AND INCREASE IN EQUAL INTERVALS.

$$\text{MAX DC TEST VOLTAGE} = R (2 \times \text{NAMEPLATE RATING}) \times 1.6$$

WHERE R = .8 FOR DC TEST ON INSTALLATION

WHERE R = .6 FOR DC TEST AFTER SERVICE

(TEST MEASUREMENTS SHOULD NOT EXCEED MANUFACTURER'S RECOMMENDATION)

Figure 5-5. Sample of completed DA Form 7468-R (side1)

SECTION D - ELECTRICAL TESTS (Continued)										
19. MEASUREMENT DESCRIPTION	VOLTAGE AND CURRENT MEASUREMENTS									
	VOLTAGE**						CURRENT**			
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N
20. LOAD TESTS AS A PERCENTAGE OF GENERATOR RATING										
	NO LOAD	25 %	75 %	100 %	110% (PRIME ENGINE ONLY)					
A-N	2400	2400	2395	2389						
B-N	2400	2400	2395	2395						
C-N	2400	2400	2392	2390						
A-B	4160	4160	4158	4155						
B-C	4160	4160	4157	4150						
C-A	4160	4160	4158	4160						
A	0	17.5A	52A	70A						
B	0	17A	49A	69A						
C	0	17A	50A	68A						
N	0	0.5A	1.4A	1.5A						
G	0	0.3A	0.4A	0.5A						
21. NOTES										
1. VOLTAGE MEASUREMENT TO BE MADE AFTER GENERATOR IS STARTED AND CONNECTED TO LOAD (CAN USE LOAD BANK).										
2. DURING COMMISSIONING OF GENERATOR SETS OR ANY EQUIPMENT, A REPRESENTATIVE OF THE MANUFACTURING COMPANY OR SUPPLIER MUST BE PRESENT TO WITNESS AND/OR PERFORM THE TESTS.										
3. ENGINE GENERATOR TESTING IS A VERY INTENSIVE PROCESS AND REQUIRES A 10 TO 14 HOUR DAY DEPENDING ON THE EQUIPMENT BEING COMMISSIONED. SUPPLIER/MANUFACTURER NORMALLY SUPPLY GENERATOR TESTING LOAD REQUIREMENTS.										
4. VERIFY ALL SYSTEM CHECK POINTS DURING LOAD CHANGES AND RECORD PER SPECIFIED REQUIREMENTS AND/OR EQUIPMENT MANUFACTURER.										
5. PERFORM AND RECORD ENGINE MANUFACTURER'S RECOMMENDED CHECKS AND INSPECTIONS.										
*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE										
**NOTE VALUE AND PHASING										

UTILITY AND GENERATOR CIRCUIT BREAKER INSPECTION CHECKLIST

For use of this form see TM 5-694; the proponent agency is COE.

SECTION A - CUSTOMER DATA

1. PLANT/BUILDING Bldg 358	2. LOCATION Fort Tank	3. JOB NUMBER 02-123
4. EQUIPMENT CB1	5. CIRCUIT DESIGNATION Feeder 1	6. DATE (YYYYMMDD) 20020823
7. TEST EQUIPMENT AND CALIBRATION DATE AVO Tester / 7 Mar 2002		8. TESTED BY John Smith

SECTION B - EQUIPMENT DATA

9. MANUFACTURER AVO	10. STYLES/S.O.	11. VOLTAGE RATING 600V	12. CURRENT RATING 2000A
13. CIRCUIT BREAKER SIZE AND INTERRUPTING RATING 200A / 50kA		14. EQUIPMENT CLASSIFICATION Air	15. FREQUENCY 60hz

SECTION C - VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

16. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
EXTERIOR OF EQUIPMENT	A		BRACING	A	
COMPLETENESS OF ASSEMBLY	A		PROPER PHASE CONNECTIONS AND COLOR CODE	A	
ELECTRICAL/MECHANICAL INTERLOCKS	A		HAZARDOUS LOCATION	A	
PROPER GROUNDING	A		WORKING CLEARANCE	A	
CONTACT RESISTANCE	A		ANCHORAGE	A	
AUXILIARY WIRING	A		REFERENCED DRAWINGS	A	
PROPER LUBRICATION	A		CHECK MANUAL OPERATION OF CIRCUIT BREAKER AND RELAYS	A	
TIGHTNESS OF BOLTED CONNECTIONS	A		RELAYS TESTED (ACCORDING TO ELECTRICAL STUDY RECOMMENDATIONS)	A	
EQUIPMENT IDENTIFICATION	A				

SECTION D - ELECTRICAL TESTS

17. INSULATION RESISTANCE @ 1000 V	A-GRD	B-GRD	C-GRD	A-B	B-C	C-A
	10 megohm	12 megohm	12 megohm			

18. NOTES

1. MANUFACTURER'S INSTALLATION TESTS/CHECKS SHOULD BE IMPLEMENTED.

*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE
 **NOTE VALUE AND PHASING

DA FORM 7469-R, AUG 2002

USAPAV1.00

Figure 5-6. Sample of completed DA Form 7469-R

BACK-UP POWER SYSTEM INSPECTION CHECKLIST

For use of this form see TM 5-694; the proponent agency is COE.

SECTION A - CUSTOMER DATA

1. PLANT/BUILDING Bldg 31d	2. LOCATION Fort Tank	3. JOB NUMBER 02-131
4. EQUIPMENT Switchgear/ controls	5. CIRCUIT DESIGNATION Main	6. DATE (YYYYMMDD) 20020823
7. TEST EQUIPMENT AND CALIBRATION DATE Fluke 45/ 7 Aug 2002		8. TESTED BY John Smith

SECTION B - EQUIPMENT DATA

9. MANUFACTURER Siemens	10. STYLES/S.O.	11. VOLTAGE RATING 5 kV	12. CURRENT RATING 2000A
13. EQUIPMENT CLASSIFICATION Outdoor	14. FREQUENCY 60hz	15. WET BULB TEMPERATURE 65 F	16. DRY BULB TEMPERATURE 85 F

SECTION C - VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

17. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING	A		WIRING VISUAL VERIFICATION	A	
ENERGIZE AND TEST SYSTEM	A		UTILITY TRIP/GENERATOR BUILDING LOAD TEST	A	
INSTALLATION INSPECTION/TESTING	A		TIGHTNESS OF BOLTED CONNECTIONS	A	
GENERATOR CONTROLS AND FUNCTIONS	A		CHECK FOR PROPER SIZE BREAKER	A	
WIRING CONTINUITY TESTING	A		REFERENCE DRAWINGS	A	
WORKING CLEARANCE	A		PROPER PHASING CONNECTIONS AND COLOR CODE	A	
SWITCHGEAR CONTROL FUNCTIONS	A				
PERFORM AUTOMATIC TRANSFER SYSTEM (ATS) FUNCTIONS UNDER THE ADJACENT CONDITIONS.	A. OPERATE NORMAL POWER			A	
	B. ALL GENERATORS OPERATE			A	
	C. GENERATORS 1 AND 2 OPERATE			A	
	D. GENERATORS 2 AND 3 OPERATE			A	
	E. GENERATORS 1 AND 3 OPERATE			R	2.
	F. RETURN TO NORMAL POWER AFTER EACH OF THE ABOVE TESTS				
	G. PARALLEL WITH UTILITY UPON RETURN TO NORMAL POWER (ITEMS B THROUGH E)				

SECTION D - ELECTRICAL TESTS

18. MEASUREMENT DESCRIPTION	VOLTAGE AND CURRENT MEASUREMENTS										
	VOLTAGE**						CURRENT**				
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
Total at Output	277	277	275	480	480	478	600	600	600	1.5	0.5
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

19. NOTES

- CHECK FOR PROPER GROUNDING CONNECTIONS PRIOR TO ENERGIZING.
- DOES NOT OPERATE WITH THIS SEQUENCE.

*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE

**NOTE VALUE AND PHASING

DA FORM 7470-R, AUG 2002

USAPAV1.00

Figure 5-7. Sample of completed DA Form 7470-R